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# PROBLEMS WITH UTILITIES DELIVERY IN NORTHERN REGIONS CAUSED BY SNOW

by

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Templeton Engineering Company[1]

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# PROBLEMS WITH UTILITIES DELIVERY IN NORTHERN REGIONS CAUSED BY SNOW

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## ABSTRACT

A case study of Baker Lake, N.W.T. is presented as a result of our involvement with formulation of a development for the community. Snow and snow drifting severely affects utilities delivery in Baker Lake as some homes become completely buried by snow. Conventional water and sewer services by tanker truck are hampered by blocked streets and sharp-faced drifts up to 6 m (20 ft) high. Low ground pressure vehicles that can follow the long tapered hard-packed snow drifts rather than blocked streets are used for delivery and pick-up. Other problems with surface facilities as a result of snow are also addressed, such as access to water plants or truck fill points and disposal sites; interference with fire-fighting equipment and the scheduling of limited heavy construction equipment; and, the cost implications of snow clearing.

Problems are highlighted with use of visual aids.

## INTRODUCTION

This paper is being presented to highlight snow-modelling techniques as a consideration when planning and engineering are carried out in Northern Regions. We have chosen to use Baker Lake, N. W.T. as a case study since snow related problems played an important role when a Development Plan for the community was being prepared.

Even though most problems with utilities delivery caused by snow are subconsciously known, itemizing them may give a greater insight into the magnitude of the problem. The question most frequently asked is "When is snow a real problem"? This can only be answered by those affected when the measure of the problem, whether it be monetary, in-

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convenience or a threat to life is of a magnitude that makes an impact. It is felt that the following partial list of snow related problem areas are of a magnitude that warrant investigation to find solutions to lessen related impacts:

- hinderance to effective distribution of services such as fuel, water, garbage, sewage collection etc. by vehicles.
- Inaccessability to service-related structures such as pump-houses, garages, etc. caused by snow drifting.
- Snow-drifted dwellings with associated hardships and hazards such as fire protection, inconvenience of snow clearing, snow loads, forced chimney extensions and others.
- Impedance to traffic movement, cost of clearing, provision for snow storage and effects on vehicular and pedestrian safety.
- Prevention for the effective performance of drainage structures during spring run-off.
- Increased cost and decrease on the margin of safety in management of airport related facilities.

Snow modelling can be used to solve or prevent problems caused by either too much or too little snow. In the case of too much snow, modelling can be used for total community siting, subdivision placement, building siting and orientation, roadway and parking location, or ditch and channel configuration. When the problem is too little snow, the technique can be used to determine how best to trap snow to ensure sufficient water supplies and to accumulate snow at predetermined locations to be used as a construction material for structures such as snow barriers and snow roads.

Although advances have been made in snow modelling in recent years, the technique has not played as important a role as warranted in the design process to date. It should be playing a larger role in the design and operation of field installations. People seem more inclined to live with snow problems, rather than design for them. They would rather fight the snow and wind rather than design to co-exist with them;

and, at the same time snow modelling could substantially reduce manpower needs, inconvenience and costs.

BACKGROUND

The firm of Templeton Engineering was chosen by the Baker Lake Hamlet Council to carry out an overall Development Plan. It became obvious from interviews with residents and field observations that the snow drifting phenomenon (snow burying may be a more descriptive term) was a major concern; so much so, that some local residents suggested re-establishing a new settlement on the opposite shores of Baker Lake where annual snow accumulation was minimal.

Baker Lake is a community of about 1100 people located 180 miles west of Hudson Bay and 150 miles south of the Arctic Circle. Situated on the Pre-Cambrian Shield, the terrain is characterized by rock, tundra and lakes. Although precipitation normally averages only 8.38 inches per year, the long winter ensures a supply of snow from mid-October to early June. With virtually no natural shelter winds of very high velocity occur and blowing snow is common.

One of the most severe problems facing the community of Baker Lake is blowing snow accumulating in abnormally high drifts in many of the residential areas of the community. These drifts are so dense that one can walk over them with less than 1/4" penetration. The barrenness of the terrain causes snow to be brought into the settlement by wind from miles to the north. It is common for several houses to be completely buried in winter with only extended chimneys appearing from below the drifts. Most houses, but primarily the most northerly two or three rows of housing, are completely surrounded by drifts, making entrance difficult, and digging-out each morning is a common task. Many residential streets in mid- or late-winter are recognized only by the geometric layout of houses as large drifts cover them. Residential streets become impassable to normal vehicles in early winter. Low-ground-pressure vehicles must be used to provide water, fuel and sewage removal services. These tasks are made difficult by the large drifts, burying entrances to houses and fuel tanks. The threat of these delivery vehicles accidentally driving over and through a buried roof or

pulling down power lines due to reduced clearance is ever present. However, the greatest hazard caused by snow drifting possibly relates to fire safety. The major benefit of the drifts is the insulation value created by the snow surrounding houses -- the worse the drifting problem the better the insulation effect.

There were three main objectives of the study:

1. To examine methods of reducing snow drifts in the settlement.

2. To recommend where residential development should take place so as to minimize effects of snow drifting on new houses and associated services.

3. To construct a physical model of the immediate Hamlet area used in the study for future use as a tool to show residents what their Hamlet will look like and as an aid to zoning by-laws.

A fourth objective evolved during the study:

4. To determine how and which aspects of a community structure can be designed to co-exist where snow drifting cannot be reduced.

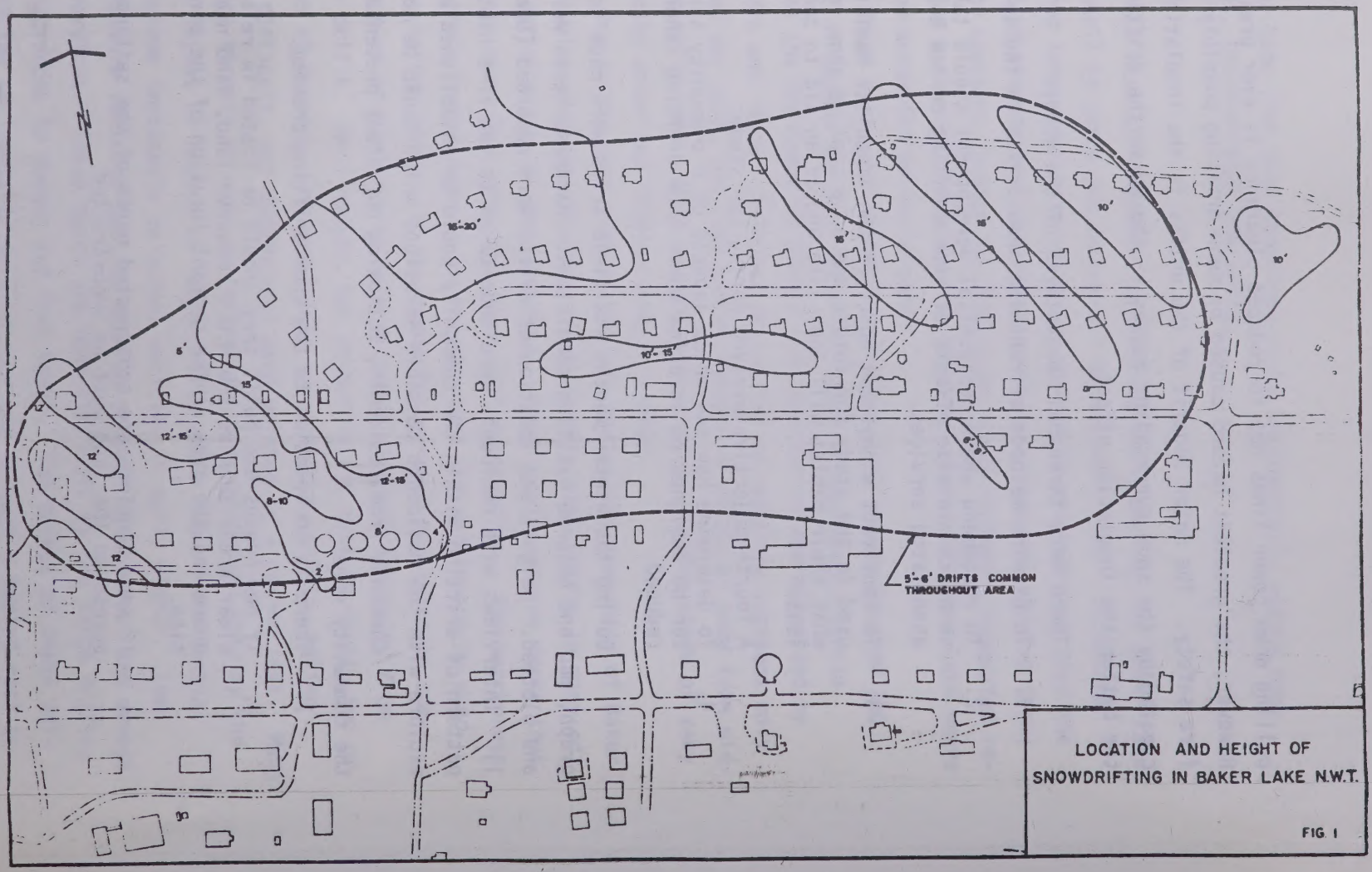
During the winter months six field trips were made to photograph, map and observe existing conditions. Hardness tests were taken and plotted. Heights and location of drifts were recorded (See Figure 1). Interviews with residents were undertaken to see if a historical pattern of drifting within the community could be established and to explore with the residents possible solutions which could be modelled.

Comments from residents, following our study presentation to the community were:

1. There is no solution to the snow drifting problem.

2. If new houses are built they should be loated in relatively clear areas such as the M.O.T. reserve land, land near the shore and the area at the present location of the airport site.

3. If snow barriers are constructed north of the settlement access to the land must be unobstructed.




LOCATION AND HEIGHT OF SNOWDRIFTING IN BAKER LAKE N.W.T.

FIG. 1

4. If snow barriers are the solution, enough snow should still be present in the settlement for snowmobile travel.

5. Whatever solution, if any, is attempted, reducing snow problems should not occur at the expense of creating worse conditions for others.

During discussions it was stressed that the philosophy of the study was to use snow as a construction material in attempting to lessen snow drifting. This idea compliments the Inuit's method for igloo construction. It was stressed that funding can be more easily received from government sources if modelled solutions could be field tested prior to constructing permanent solutions at great expense.

During the study, members of the Baker Lake Hamlet Council and Planning Committee were flown at various times to observe and comment on the accuracy of drifting patterns simulated by our modelled townsite. Representatives of M.O.T. and Territorial Government also viewed the model and their comments were vital to the success of the study.

A constant dialogue was maintained with residents to ensure that those solutions which appear favourable on the snow-model were also acceptable, if their use was to be implemented in the community.

## PHYSICAL MODELLING

### General

Three hydraulic models were constructed relating to Baker Lake; one at a scale of one to one-thousand (1:1000) of the whole townsite and the surrounding terrain; another at a scale of one to four-hundred (1:400) of a strip through Baker Lake paralleling the prevailing wind direction; and, a third at a scale of one to four-hundred (1:400) in the vicinity of a proposed recreation centre.

### Model Construction

Whole Townsite and Surrounding Terrain. This model was approximately 8 feet wide and 12 feet long. The townsite was constructed on an 8-foot diameter base to facilitate turning the town to simulate changing wind directions, if necessary. The base was constructed of wood, concrete and plasticine. The concrete and plasticine allowed the

terrain to be shaped approximately to scale, while the plasticine within the built-up section of the town facilitated easy placement and rearrangement of buildings. Houses, tanks and other structures were constructed of wood.

Strip Through Baker Lake. This model was constructed on a flat 1/2-inch piece of plywood, 2 1/2 feet by 5 feet. Houses, tanks and other structures were constructed of wood except for two domes that were made of plastic. The terrain was not modelled so that the reduced vertical height and a constant water velocity (wind speed) over the buildings could be accomodated in the hydraulic flune.

Recreational Centre. This model was constructed of 1/2-inch plywood, 3 feet wide and 8 feet long at a scale of 1:400, generally similar to the strip model. Houses and other structures were constructed of wood. No attempt was made to model the topography because of its adverse effect on the velocity. The purpose of this model testing was to select the orientation of the recreation centre that would minimize adverse effects of snow drifting.

Model Testing and Unresolved Difficulties

Whole Townsite and Surrounding Terrain. This model was tested in an eight-foot wide hydraulic flume using a water discharge of 3.45 cfs and a 9-inch water depth over the town. This resulted in a water velocity upstream of 0.86 fps and overtown of 0.575 fps. Sand was introduced to the water at a rate of 3 lbs/minute over a forty minute period to simulate blowing snow over a full winter. This arrangement was arrived at because it best simulated the later winter drifting pattern observed in Baker Lake and hence resulted in a qualitative approach. Meeting more strict hydraulic model criteria was not possible because water velocities much higher than 0.575 fps resulted in dunes progressing through the model. The height of dunes exceeded most building heights and therefore destroyed drifting patterns around the modelled buildings.

Another major problem with this model resulted from the particular topography at Baker Lake and the limitations of water depth available in the laboratory flume. Even at the scale of 1:1000, the model

had an elevation difference of three to four inches from one side to the other. Using a six-inch water depth over the upper part of the terrain resulted in 9-inch water depth over the lower town. Therefore, sand carried over the town naturally settled out over the town due to the slower velocity. This resulted in two detrimental effects: sand deposited upstream of the town, while in reality little snow accumulated on the tundra upwind of the town; and, secondly, there was more sand deposited in the lakefront area of the town than there is snow in reality. It was observed that this model resulted in uniform deposition of sand over the town with some drifting superimposed on it, but it did not represent the field conditions accurately. Local residents and government personnel, however, were generally surprised at the visual simulation achieved.

Problems were encountered as a result of uniform deposition over the town. For example, six- or eight-foot high snow fences could not be adequately modelled because the height of natural deposition of sand exceeded the scaled height of the fence. Nevertheless, several other adaptations to alleviate the drifting problem were carried out on this model and are described below.

Snow Fences. Snow fences equivalent to six-foot height were installed upstream of the town about 6 inches (550 ft field) from the perimeter houses. As expected from the previous discussion, the snow fences had no visual effect on the drifting situation in the town. The snow fences became buried very quickly. Snow fences would have some merit in collecting snow out on the tundra upstream of the town. Such snow could be pushed up into snow barriers as described.

Continous Snow Barriers. Simulated continuous snow barriers 20-feet high (vertical face to the wind) were constructed approximately 6-inches and 1-foot (500 and 1000 feet in field) upwind of the town. Barriers became covered with sand at the equivalent of about Feb. 10, and by the end of winter there was no apparent difference in drifting within the town.

Because the effect of 20-foot high barriers was subdued somewhat by the sand settling out upstream of the town, the barriers were placed continuously at an exaggerated vertical scale (equivalent of 40-

feet high). Although more effective in trapping snow, these high barriers still had no visual effect on drifting within the town.

Staggered Snow Barriers. Staggered snow barriers at an exaggerated vertical scale were constructed approximately 1000-ft upwind of the town. This arrangement trapped more snow than the continuous snow barrier.

Houses Off Ground. All houses were raised five feet off the ground on stilts in an attempt to get more snow to pass through the town. Although the houses appeared to be much more free of sand, the volume of sand retained in the town indicated that little, if any, more snow passed through the town. The clearer condition around the houses observed visually was probably because the houses were raised above the accumulated sand or because of redistribution (more uniform depth).

Houses on Gravel Pads. All houses were set on 5-foot high simulated gravel pads. This method also left houses much clearer of snow than the original situation, particularly where houses are normally buried. However, again this effect was from the raising of houses or redistribution of drifting because about the same volume of sand was retained in the town.

Houses Oriented into Wind. In this arrangement houses were oriented at ground level so that the narrow dimension of the house faced into the wind.

It was found that this arranagement left houses clearer; that is, no houses were buried. It was noted that the southwest part of town still had the most drifting. However, the benefit of this arrangement was from redistribution because about the same volume of sand was retained in the town.

Houses Oriented Corner to Wind. This arranagement showed some advantage because again no houses were buried. It was observed that this arranagement showed some promise and should be tested at a larger scale.

Streets Re-Aligned. Streets were oriented to parallel the direction of the prevailing winds and houses were placed adjacent to these streets. This arranagement left houses unburied but the concentration of snow occurred between the rows of houses on streets.

Variety of Housing Shapes. Since field observations showed that the existing oil tanks and geodesic dome houses remained relatively clear, these shapes and others were modelled. If placed behind the settlement, geodesic dome houses remained unburied at the side facing the wind but created large dunes downstream. Adjustments to the geodesic dome shaped resulted in similar drifting patterns. A long trailer-type house was also modelled but no drifting relief was observed.

Model Cleared of Houses. The present site of Baker Lake on the model was completely stripped of houses for the final run. About the same volume of snow was retained in the boundaries of the townsite. This is contrary to the long-term observations of local resident, Mr. Ken McCulloch. Unfortunately, we were not aware of Mr. McCulloch's familiarity with the study area until all the testing at this scale was completed. It is obvious with Mr. McCulloch's experience that the model cleared of houses should have been tested first. However, at the beginning of the model testing our only initial condition was that particular houses were buried at the end of winter.

Mr. Ken McCulloch, a 21-year resident in Baker Lake, was contacted to determine the drifting condition at the Baker Lake townsite before many of the buildings were erected. He indicated that the townsite itself without buildings was generally not prone to a drifting problem, except at the east end of the townsite below a steep slope where a 30 ft drift is common. He emphasized that drifting is generally around buildings and other obstructions such as tanks. To stress this point, he stated that at one time several houses were constructed in one location but had to be moved to another snow-free area when the drifting problem became apparent. A similar drifting problem developed at the new site.

Mr. McCulloch also noted that the drift pattern varied from year to year. This is to be expected because the wind direction during or after the first snowfall is important in establishing drift obstructions for subsequent storms. Variations in wind direction and intensity from year to year in addition to variations in snowfall can be expected to produce considerable drift patterns from year to year.

Strip Model. In construction and testing the 1:400 scale model of a portion of the town no attempt to simulate the topography of the area was made. The limited depth of water available in the 2.5-foot wide flume precluded such construction, but more importantly a constant water velocity was desired.

In the first series of runs, sand was aerially dispensed onto the model through a plexiglass dispenser mounted across the flume. Experiments with variations in dispensers, dispensing rate, and dispenser position resulted in excellent simulation of snowdrifting on the model. Houses in the first three upstream rows were drifted to the rooftops and a number of houses in the second and third rows were completely buried as observed in the field. Long snake-like drifts the height of house eaves were formed through the centre of the model, and drift patterns around the school, tanks, and geodesic domed homes agreed with field observations. Eight proposed houses placed on the model in place of existing tanks were drifed to the rooftops.

Possible Field Solutions Tested. Various methods of snow-fencing were modelled while using the plexiglass dispenser. Three rows of 3/4" high (25 foot field) curved simulated snow barriers were placed 400 ft from the perimeter houses. Where the curve of the barrier pointed into the direction of the water entirely clear areas were observed extending through the model. Two rows of similar simulated snow barriers were constructed in an attempt to create the same effect as previously described. The same clearing was observed extending from the concave face of the barriers. Two rows of staggered meshed wire snow fences (30 foot field high) were also modelled and resulted in less burying of the perimeter houses.

A second series of runs was made with a quantity of sand placed in front of the model and the flowing water carrying the sand downstream onto the model. Similar drifting patterns were observed on the model as before; however, large dunes formed in front of the model. A 3/4 in. high (25 foot field) continuous snow barrier placed on the model 10 inches (330 feet field) from the perimeter houses was high enough to cause an increase in flow velocity and the sand was acceler-

ated over the barrier rather than being trapped by it.

One final run was made after raising the houses 1/6-in. (5 ft field) off the base. Drifting patterns throughout the town were the same as before, however, clear areas around the perimeter of houses were observed.

Recreational Centre. This strip model of Baker Lake covering the recreational area was tested in a 3-foot wide, 44-foot long hydraulic flume where good control of quantity and depth of flow would be maintained. After many preliminary runs using Ottawa Sand F-140 to simulate snow it was found that a discharge of 2.0 cfs, depth of flow of 11 inches, resulting in a velocity of 0.73 fps best represented the drifting patterns of Baker Lake.

The model was run first with no proposed recreation centre in place. It was noted that little natural drifting occurred in the proposed recreational area without the centre in place, but other areas were adequately simulated. The model was then used to test five basic alignments.

Southerly Alignment - Entrance at South End. Of the five alignments tested this alignment produced the most severe drifting at the entrance to the recreational centre. The opposite end being clear of snow suggested a $180^{0}$ rotation of alignment. Snow load on the main arch structure was substantial.

Northerly Alignment - Entrance at North End. This alignment appeared to protect the entrance from accumulating snow when wind is from the north. It was deduced from these first two tests that winds from the south (seldom causing blowing snow) would congest the entrance if strong enough to produce blowing snow. Snow load on the main arch structure was substantial.

North-Northwest Alignment - Entrance to Northwest. This alignment caused drifts very similar to the Northerly Alignment. This suggested that winds from the north and northwest (which are the directions of wind most likely to cause blowing snow) will keep the entrance clear. Snow load on the main arch structure was substantial.

Alignment Parallel to Main Street - Entrance to Northwest. With the recreation centre oriented parallel to Main Street the entrance remained clear of snow. It should also be noted that the snow load on the main arch was substantially reduced with this alignment.

Alignment Perpendicular to Main Street - Entrance to Northeast. With the recreation centre oriented perpendicular to Main Street the drifts encroached on the entrance although the entrance remained clear of snow. It should be noted that the roof load with this alignment appeared the heaviest of the five alternatives studied.

Recommendations from Model Test Results

Whole Townsite and Surrounding Terrain. Results from this model indicated that large obstructions upwind of the townsite will have the effect of lessening the amount of snow drifting within Baker Lake and that staggered intermittent barriers such as might be constructed by end-dumping and/or pushing snow up with a dozer are more effective than a continuous barrier. Evidence of the effectiveness of even staggered intermittent barriers was not strong enough to warrant a recommendation that the method be totally adopted. It was recommended, however, that a test section of about 1000 ft length be constructed by end-dumping snow 500 ft upwind of the nearest houses presently severely affected by drifting (for example, those immediately northwest of the large tanks). Should such barriers prove advantageous, larger sections should be field tested; the model should be resurrected to guide field testing; and the economics of permanent barriers and their effectiveness should be evaluated.

Other tests with this model were undertaken to evaluate future housing sites least affected by drifting. Tests indicated that in all cases, houses oriented in rows into the prevailing wind direction were less obstructed by drifted snow than existing house orientations. Houses added upslope around the periphery of existing houses (that is, east-west streets) caused some existing houses to become buried that currently do not become buried; and, the added houses themselves were largely engulfed by drifts. Of the areas tested, the most promising for new houses (in north-northwest rows) are near the

present M.O.T. sites at the east end of town and near the existing north-northwest oriented houses at the west end of town. At both sites, extending existing rows was satisfactory because such oriented houses remain relatively clear and do not tend to become buried, but the streets between rows become severely drifted. Servicing by conventional vehicles could therefore remain a problem even with streets oriented into the wind.

Strip Model. Results from this model lead to the following recommendations:

1. Should the existing tanks be removed, the tank site should not be used for single-storey traditional housing.

2. Field testing of snow barriers as described previously be undertaken.

3. Raising single-storey houses above ground level not be considered a feasible solution to Baker Lake snow drifting problem. Raising the houses does appear to prevent inundation of houses, but it does not appear to lessen the amount of snow retained in the town.

Recreation Centre. Results indicated that an alignment with the entrance facing north to northwest would best keep the entrance to the recreational centre clear of snow. Because winds most likely to cause blowing snow are predominantly from the north or northwest, it is suggested that a recreation centre located parallel to Main Street (northwest) would give protection to the entrance through a wide range of wind directions that occur frequently. Over 70 percent of the time when there is wind at Baker Lake from October 1 through May 31 it is blowing from the north or northwest. In addition, this northwest alignament appears to minimize the amount of snow that accumulated on the arch roof.

## PROBLEMS IN MODELLING SNOW DRIFTING

### General

Problems arise in modelling snow drifting on both theoretical and practical grounds. Most practical problems can be overcome, but use of sand in flowing water to simulate snow (ice particles) in air has inherent theoretical problems.

Theoretical Problems. Theoretical work over the past few years on snow drifting has attempted to rigorously define the modelling criteria required to simulate drifting snow carried by air with sand carried by water. With the range of practical length scales from about 1/50 to 1/1000, the geometric length scale cannot be met because the ratio of snow particle diameter to sand particle diameter would generally be much larger (eg. 1/1 or 1/10). Thus distorted time scales and unnatural depth build-up result, and the use of sand in water becomes a more qualitative than quantitative approach. Nevertheless, undistorted scaled lengths are used in the qualitative approach.

Following the latest available theoretical work (Calkins 1975), it appears that the choice of geometric scale and an exact flow velocity scale are not critical because of Reynolds number (R) independence for flow conditions with $2 \times 10^{-4} < R < 2 \times 10^{-6}$. Therefore, in channels with a hydraulic radius of 0.20 to 0.63 (as used in these studies) Reynolds number independence should exist for velocities greater than 0.33 ft/sec. Velocities in this study were more than double this value.

Practical Problems. It cannot be over emphasized that snow drifting models at present are qualitative only, and can be used only as an indicator of the applicability of proposed solutions of snow drifting problems. They are particularly useful within an area where snow drifting patterns are known in the field, and can be duplicated with the model. Changes of snow drifting patterns within the area of the model due to the addition or deletion of buildings can then be used as qualitative evidence of what may happen when corresponding changes (eg. addition or deletion of structures) are made in the field. However, because the large depth of air mass (wind) in field conditions is modelled by only a few inches of water in the model, it is important to keep the vertical height to be modelled to a minimum. In other words, relatively flat terrain or solutions not involving relatively large obstructions in the vertical dimension are more closely modelled by this qualitative technique than terrain or obstructions with large vertical changes in elevation.

Other minor practical problems experienced relate to the type, size and cost of sand, the cost of water, the size of model, and recognizing when field conditions are best simulated by the model. Although a number of size ranges of Selkirk Silica sand were used in the whole townsite and surrounding terrain and strip models, the finest available (60-100) sand gave the best results. For the Recreation Centre model, Ottawa F-140 sand was used and give good results - even better than the finest Selkirk Silican sand. However, F-140 sand was more than double the cost of Selkirk Silica sand, and more than five times the cost if purchased in small quantitites.

In operating models in large flumes, recirculating water systems can essentially eliminate the cost of water, but minor pumping costs will be incurred. However, with recirculating systems proper sand traps must be provided to alleviate wear on pumps. Because fine sand is used in modelling snow problems, it is almost impossible to eliminate all sand from return water.

The maximum size of model is determined largely by the minimum representative area to be modelled and the largest available flume, with some consideration given to the depth of water than can be handled in the flume. Minimum size of model is more related to hydraulic parameters discussed under Therotical Problems.

Recognizing when field conditions are best simulated by the model depends upon field reconnaissance work and on information from local residents. The pitfall of this approach is that although the model may appear to represent the field use, the mechanism of sand deposition may differ largely from the snow drifting process. In such cases, solutions indicated by model results of field installations may differ considerably from the actual drift behavior around the field installation when constructed.

## APPLICATIONS

An immediate application of our results and recommendations from model testing was the Baker Lake Hamlet's initiative to implement constructing snow barriers at designated locations in the community

this winter. One particular location was at the previously impassable road from the settlement to the airstrip. Reports from the community have stated that these recently constructed snow barriers have kept the road open for the first time in many years.

Another beneficial result from our recommendations came from the Housing Corporation in Yellowknife who previously had difficulty in preventing delapitated houses from being habitated by families. This problem can now be avoided since residents are in favour of having these dwellings moved to experimental future residential sites for monitoring the effects of snow drifting on these unoccupied dwellings.

Since the conclusion of our study many of our varied clients have expressed much interest in our work. Using their backgrounds we feel the following programs and projects should consider snow-model testing:

1. Land Assembly Programs - Model can be used to demonstrate effects of snow on proposed development not anticipated prior to consolidation of property and leading to construction.

2. Orientation of new buildings and design of roof geometry to avoid constant drifting at entrances or parking facilities as well as avoiding unnecessary snow accumulation on roof areas.

3. Route selection of roads and highways as well as grade and cross-sections to prevent snow blockage for travel.

4. Design of drainage courses, from local community to agricultural and floodway channels to unnecessarily create catchment areas for snow accumulation which may effectively reduce rate of run-off.

5. Retention of snow for water supply, snow roads, insulating component and as desired snow barriers from wind and drifting snow.

6. Architectural design of residential dwellings which are to be located in an unavoidable snow accumulation area. Exits may be located through a roof and various deflectors used to keep exits drift free.

7. Any proposed tree planting programs to be used for shelterbelts or aesthetics should be modelled to indicate effects.

8. Location of camps and temporary landing sites for the oil and mining exploration industry.

9. Airport facilities using deflection measures to keep landing lights as well as other facilities clear of snow.

10. Linear surface structures such as pipelines and collector systems associated with the gas and oil industry.

11. Research on biological environments influenced by depth of snow or water (eg. migration routes and fish ponds).

12. City works and operation departments who deal with snow clearing and snow storage programs.

13. The planning and standardization of development criteria to study optimum utilization of public right-of-ways as they relate to the geometrics and dimensions affecting snow clearing and storage.

## RECOMMENDATIONS

Further to previously noted results of recommendations following our testing procedures, since Baker Lake appears as an ideal location with corresponding snow drifting phenomenons we felt experimental programs should be initiated in the community to monitor solutions which may have national as well as international application.

The following were recommended "pilot" experimental programs for implementation before more exhaustive and expensive programs are begun:

i) build test sections of snow fencing using snow as the construction material

ii) align new streets based on prevailing winds commencing with a short experimental section

iii) align abandoned houses in future residential areas to study snow-drifting effects over one winter season

iv) construct experimental dwellings which are specifically designed to be buried, and survey inhabitants over one year

## CONCLUSIONS

It has to be recognized that man's presence in a northern environment will invite snow related problems. A key to his ability to adapt is to first recognize the problem and secondly to either cope with it or find solutions to lessen or eliminate the problem.

A sand-water model will assist to anticipate, observe and study potential snow problems, but in addition it will assist in finding solutions at a reasonable cost. Since the cost of constructing and operating a model is minimal compared to constructing field solutions that may not work, the case for investigating model use for snow problems cannot be stressed enough.

For many southern professionals designing facilities for northern regions, it is only human to down-play snow problems unless they have been personally encountered. Even once recognized as a problem, conceptual solutions should be verified before constructed.

On the other hand snow drifting studies, like all studies, are meaningless until constructive action is taken. For those in a position to implement recommended actions and to fund solutions, the existing problems are for the most part impersonal. Unless one "puts himself in their place" and realizes that problems of utilities delivery caused by snow can be minimized, attitudes will be difficult to change.

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